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MIDDLE DEVONIAN STRATIGRAPHY IN CENTRAL PENNSYLVANIA— A REVISION

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DEPARTMENT OF ENVIRONMENTAL RESOURCES
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by **Rodger T. Faill**
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PREFACE

Stratigraphy, the study of layered rocks, enables the geologist to trace rock formations of similar age and character over long distances. The Middle Devonian rocks (about 375 million years old) in central Pennsylvania have been given stratigraphic names for the past 95 years. However, recent detailed mapping in this area has led to the recognition of upward-coarsening sedimentary cycles in these rocks. As a consequence, a more coherent Middle Devonian stratigraphy has been developed, and is presented in the following report. Directed primarily to professional geologists, this report will enhance their understanding of the rocks of this age and contribute to better geologic interpretation and specific, on-site evaluations.

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PLATE

(in pocket)

Plate 1. Fence diagram of Middle Devonian stratigraphic units superimposed on map of the Mahantango Formation in central Pennsylvania.

MIDDLE DEVONIAN STRATIGRAPHY IN CENTRAL PENNSYLVANIA—A REVISION

by

Rodger T. Faill, Donald M. Hoskins, and Richard B. Wells[1]

ABSTRACT

Stratigraphic names for Middle Devonian rocks in central Pennsylvania evolved through a series of regional reports beginning with White (1883) and Claypole (1885) and culminating in Willard and others' 1939 volume, *The Devonian of Pennsylvania*. Detailed mapping in this region began with Miller in 1961 and continues. The most recent mapping (Faill and Wells, 1974; Hoskins, 1976) and a regional report (Kaiser, 1972) demonstrate that the Middle Devonian rocks were deposited in repetitive, asymmetric, upward-coarsening cycles in a delta whose apex was in the vicinity of Harrisburg, Pennsylvania.

Each cycle characteristically begins with black to dark-gray, silty claystone at the base. Grain size progressively increases upward to sandstone, conglomeratic sandstone, or (rarely) conglomerate. Directly above the coarse-grained beds, grain size abruptly decreases to claystone or siltstone, marking the base of an overlying cycle. The cycles range in thickness from 6 to 250 feet (2 to 75 m) and persist laterally for as far as 50 miles (80 km). This lateral persistence of the cycles enables mapping and correlation across south-central Pennsylvania and the establishment of a revised stratigraphic framework defined by the more prominent cycles.

The stratigraphic names Shamokin, Mexico, Mahanoy, and Fort Hunter are abandoned and the name Marcellus Formation is returned to the meaning it had when first used in this area of Pennsylvania. The Marcellus is overlain by the Mahantango Formation consisting of the Turkey Ridge, Dalmatia (new), Fisher Ridge (new), Montebello, Sherman Ridge, and Tully Members. The Tully is included within the Mahantango because of its lithic similarity to the Sherman Ridge Member.

INTRODUCTION

Throughout much of Pennsylvania and western New York, the Middle Devonian rocks consist of fine-grained marine clastics (shales and minor amounts of siltstone) containing several limestone units throughout the sequence. In south-central Pennsylvania, however, the Middle Devonian is

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represented by a thick sequence of sandstones and conglomeratic sandstones, siltstones, and shales. These coarse clastics are thickest in the southernmost Devonian exposures a few miles west of Harrisburg in the New Bloomfield and Loysville quadrangles, and the percent of sandstone and the grain size in the sequence decrease to the east, north, and west. This areal pattern (originally noted by Willard, 1935, p. 218, and amplified by Kaiser, 1972) suggests that a major point of sediment input was located southwest of the Harrisburg area during the Middle Devonian.

Recent detailed mapping in five 15-minute quadrangles (Mifflintown, Millerstown, Millersburg, New Bloomfield, and Loysville) in the Valley and Ridge province north of Harrisburg (Plate 1) has provided additional data to delineate more correctly the general nature of these coarser rocks and their relationship to the finer grained rocks further to the east, north, and west, and to revise the stratigraphic nomenclature.

These coarser rocks represent a delta (Willard, 1935; Willard and others, 1939, p. 197) that was built out into the Middle Devonian marine basin. In the depositional area, the Middle Devonian rocks have a characteristic pattern of asymmetric, upward-coarsening cycles first noted by Faill and Wells (1970) during their mapping of the Millerstown quadrangle (Faill and Wells, 1974), and described by Kaiser (1972). Each cycle characteristically begins with dark-gray claystone at the base; grain size progressively increases upward to sandstone, conglomeratic sandstone, or (rarely) conglomerate (Figure 1; see also Kaiser, 1972, p. 44-52). Within some cycles, the increase in grain size is gradual; in others it is discontinuous (by several small, abrupt increases). In contrast, the top of a cycle is marked by a large, abrupt decrease in grain size (for example, from coarse-grained sandstone to claystone). The cycles range in thickness from 6 to 250 feet (2 to 75 m). The thinner cycles are usually nested within a thicker cycle and represent local variations within a wider area of sediment accumulation.

Not all the cycles culminate in conglomerate, or even sandstone—in some, maximum grain size does not exceed coarse-grained siltstone. Kaiser (1972, p. 52-55) has distinguished between coarse proximal cycles and finer distal cycles. This distinction is supported by the lateral decrease in grain size away from the Harrisburg vicinity in each of the cycles. Not only does the maximum grain size decrease laterally, but the amount of coarser material composes laterally a smaller and smaller percent of the entire cycle. Thus, at Williamsport (Faill, in press) and Altoona (Faill and others, in preparation), some 80 or more miles (130 or more km) to the north and west of Harrisburg, cycles are not present—instead, the Mahantango Formation consists of a homogeneous dark-gray silty shale throughout (Williamsport) and interbedded siltstones and silty shales (Altoona).

The finest grained rocks are generally dark-gray to medium- and olive-gray shales, shaly siltstones, and interbedded or laminated shales and siltstones. The siltstones and finer sandstones are graywackes to subgray-

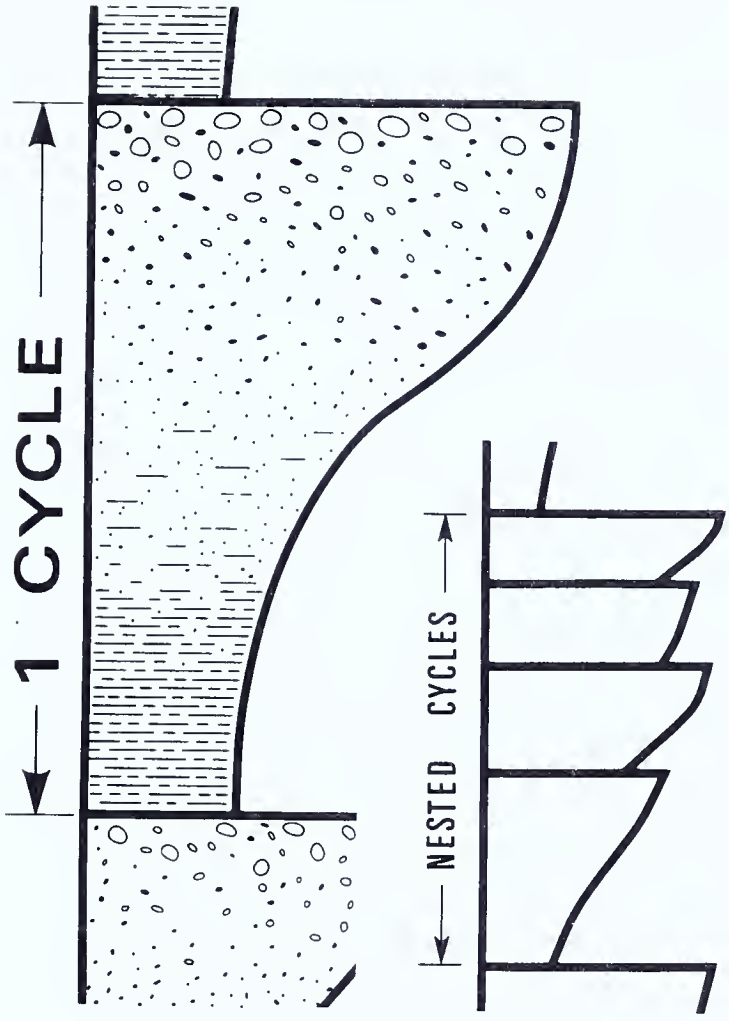


Figure 1. Idealized Mahantango upward-coarsening cycle. Grain size gradually increases upward through the cycle. The next cycle begins with the abrupt decrease in grain size from sandstone (or conglomerate) to shale or claystone. Nested cycles consist of two or more incomplete cycles, in which grain size does not attain sand size at the top.

wackes with an interstitial clay matrix surrounding subangular to subrounded quartz grains. The coarser beds are better sorted, possessing less clay matrix between the quartz grains, and are usually silicified. Conglomeratic clasts consist of quartz, quartzite, siltstone, and metamorphic rock fragments. Bed thickness generally increases with grain size (except in shale sequences, which tend to be very thick bedded). Parallel bedding predominates. Trough crossbedding occurs in the coarser beds. Kaiser (1972) discusses the sedimentary structures and interpretation in greater detail.

Fossils are most frequent in the upper part of the Middle Devonian, consisting of brachiopods, molluscs, arthropods, and crinoids that occur both as solitary individuals and concentrated in lenses. Large, thick-shelled brachiopods occur in the coarser beds at the top of some cycles, whereas the lower parts of the cycles contain a smaller, more diverse fauna. The lower members are generally less fossiliferous.

Comparison of outcrops shows that some cycles are particularly widespread, extending for at least 50 miles (80 km). Others, however, are of more limited extent, and occur at different stratigraphic positions. In spite of this lateral variation, the asymmetric cyclicity from shale to silicified sandstones results in a characteristic topography of ridges and benches that enables correlation among the outcrops. Only the larger 100- to 600-foot (30- to 180-m) cycles or groups of cycles can be traced by topography. Yet, despite the limited areal extent of many individual cycles, the wide lateral persistence of a few cycles does enable an approximate correlation over the mapped area and the establishment of a stratigraphic framework for the Middle Devonian rocks in central Pennsylvania.

PREVIOUS STRATIGRAPHIC NOMENCLATURE AND PROPOSED STRATIGRAPHY

The early development of the Middle Devonian stratigraphic nomenclature has been traced by Willard (1935, 1936; Willard and others, 1939). Initially, Middle Devonian names first used in New York, such as Onondaga, Marcellus, and Hamilton, were extended southward and applied to the Middle Devonian rocks in Pennsylvania. A few local names were developed for sequences that were different from New York or for units whose correlation was uncertain.

Thus, the Hamilton Group, as originally used in New York (Vanuxem, 1842) and in Pennsylvania (White, 1883, 1885; Claypole, 1885), included all of the rocks between the Marcellus Black Shale and the Tully Limestone (Figure 2). But a tripartite division of the Hamilton was recognized throughout central Pennsylvania, consisting of a coarser grained unit (the Montebello Sandstone, Claypole, 1885) between upper and lower shale units. Similarly, to the northeast along the Susquehanna River, White (1883) divided the Hamilton into five parts, three shale units separated by the Selinsgrove upper and lower sandstones. His Hamilton overlay both the Marcellus Black Shale (which included the Selinsgrove upper limestone) and the Selinsgrove lower limestone and shale. The work of Claypole (1891) and Kindle (1912) established correlation of White's lower Selinsgrove limestone and shale with the Onondaga Formation in New York. Willard (1935) named these two Onondaga lithologies the Needmore Shale Member and

the Selinsgrove Limestone Member, a usage that has generally been followed to this day.

The name Marcellus has had a more complex history. When Marcellus was initially carried south to the Susquehanna River basin, it was referred solely to the black shales above the Selinsgrove lower limestone (Onondaga) by White (1883) and to the Onondaga and immediately overlying black shales by Claypole (1885). Willard (1935), in his work in Juniata County, described two distinct sandstone lithologies that occurred above White's (1883) original Marcellus. Because these sandstones were thought to be overlain by a black shale that was similar to the underlying black shales, Willard expanded the term Marcellus to include all four of these units: the Shamokin Member (lower black shale member), the Turkey Ridge Member (thick-bedded sandstone), the Mexico Member (thin-bedded sandstone), and the Mahanoy Member (upper black shale) (Figure 2). On the basis of detailed mapping in the Mifflintown quadrangle, Conlin and Hoskins (1962) concluded that, although two distinct sandstone lithologies occur at Mexico, the two sandstones were for the most part indistinguishable from each other at the Turkey Ridge type area to the east. The Mexico sandstone lithology was considered a lateral facies of part of the Turkey Ridge Member, and the member name Mexico was dropped by Miller (1961) and Conlin and Hoskins (1962), leaving the Marcellus with only three members: the Shamokin, Turkey Ridge, and Mahanoy.

Miller (1961), Conlin and Hoskins (1962), and Dyson (1963) stated that the Mahanoy (shale above the redefined Turkey Ridge) was not a black shale similar to the Shamokin Member, but rather that it consisted of laminated black shale and gray siltstone, which to the south graded into the olive-gray siltstones and fine-grained sandstones of the lower Mahantango Formation. Furthermore, because the Turkey Ridge sandstones are lithologically similar to the sandstones in the overlying Mahantango Formation, and because no black shale occurs above these sandstones, Faill and Wells (1974) concluded that the name Marcellus should be returned to its original usage, the name thus referring only to the black fissile shale above the Onondaga and below the first significant olive-gray sandstone (Turkey Ridge).

This misunderstanding of the true nature of the lower Mahantango lay initially in Willard's (1935) attempt to correlate widely separated sections that have no common marker horizons; the misunderstanding was compounded by his and later workers' (Miller, 1961; Conlin and Hoskins, 1962; Dyson, 1963) erroneous assumption that the lithologies called Turkey Ridge, Mexico, and Mahanoy occurred only once in the Mahantango section. They were not aware that these lithologies (except the Marcellus) are repeated vertically and change laterally from one place to another.

For example, the dark-gray shales directly beneath the thin Montebello sandstones in Mahanoy Township (on Pa. Route 147, 2 miles (3 km) south

of Sunbury, in Northumberland County) were named Mahanoy by Willard (1935). At Blue Spring Hollow, 40 miles (65 km) to the southwest, dark-gray to black shales occur above the Turkey Ridge - "Mexico" sandstones. Apparently, Willard felt the two exposures were complete enough to conclude that dark-gray to black shales extend from Turkey Ridge - "Mexico" to Montebello and thus called this entire interval Mahanoy. However, the Mahanoy exposures are stratigraphically some 300 feet (100 m) above those of the Blue Spring Hollow outcrop. This error in correlation and the poor exposures of this interval prevented him from realizing that, over much of central Pennsylvania, most of the rocks below the Montebello are olive gray, and not dark gray to black. Because of the prevalence of olive-gray rocks and because the laminated Mahanoy lithology occurs at the base of a number of the Mahantango cycles, the term Mahanoy is abandoned as a formal name, following Faill and Wells (1974).

From work in the Millersburg quadrangle (Hoskins, 1976) it is herein proposed that the name Fisher Ridge Member be applied to the dark-gray and olive-gray shales and siltstones below the Montebello Member sandstones. These finer grained rocks are the lower portion of a very thick (1,000+ feet, or 300+ m) complex cycle culminated by the Montebello Member. The homogeneity of the lower, fine-grained portion of the cycle, its great thickness, and its large areal extent seem to justify division of this thick cycle into two mappable members.

The assumption that each lithic type in the lower part of the Middle Devonian rocks was unique also contributed to the confusion. The repetition of the Mahanoy lithology was mentioned above. The name Mexico was assigned to rocks exposed at Mexico and other localities. It is evident from notations in Willard's notebooks, such as "Dtr. ss: (Turkey Ridge) Mexico type" (notebook 38, p. 28), that Mexico applied to thin-bedded, fine-grained sandstones, and that Turkey Ridge applied to thicker bedded, medium-grained sandstones underlain by black shale. Because of the assumption of uniqueness, it was not realized that each of these lithologies is a different part of a sedimentary cycle (the upward-coarsening cycle), and that one lithology grades laterally into another. Thus, along Cocolamus Creek, Willard called some Montebello sandstones either Turkey Ridge or Mexico, depending on whether they were thick or thin bedded. To the west of Mexico, at Academia and McCoysville, the Turkey Ridge Member is thinner bedded, taking on more of a "Mexico" aspect as a lateral facies change within the cycle. The type section exposed at Mexico is now considered the lower part of an upward-coarsening cycle, the Dalmatia Member, which lies directly above the Turkey Ridge Member. Because the Mexico sandstone lithology is not unique and represents only part of a cycle, the term Mexico is abandoned, as originally proposed by Conlin and Hoskins (1962).

The general tripartite subdivision of the Hamilton (Mahantango) into two shales and an intervening sandstone (Montebello) was recognized by the early workers, and has been followed in some of the more recent work (Ellison, 1965; Kaiser, 1972). White's (1883) Selinsgrove upper sandstone is the approximate equivalent to Claypole's (1885) Montebello Sandstone. The lithic dissimilarity between the Hamilton rocks of New York and those in central Pennsylvania led Willard (1935) to propose the name Mahantango for the rocks that were exposed along West Mahantango Creek and that lay between his expanded Marcellus and the Tully. However, because all of the rocks below the Montebello had been transferred into Willard's expanded Marcellus, his Mahantango consisted of a lower Montebello Sandstone and an upper shale. Miller (1961) felt the great difference in grain size between these two units justified separation into two formations, the Montebello Formation and the overlying Sherman Ridge Formation. Because of thinning of the Montebello Sandstone to the north, and consequent increase in olive-gray shale below the Montebello, Conlin and Hoskins (1962) returned to the tripartite subdivision of the Mahantango, restricting the Mahanoy (Marcellus) to the laminated dark-gray shales above the Turkey Ridge, and placing the overlying olive-gray shales in the Mahantango. The Sherman Ridge was mapped as a formal member of the Mahantango by Dyson (1963).

To the southwest, in Bedford and Fulton Counties, Willard and others (1939) and Ellison (1965) use the terminology of Gander Run, Chaneysville, and Frame Members for a threefold division of the Mahantango. It cannot be assumed that they are directly equivalent to the Fisher Ridge, Montebello, and Sherman Ridge Members. No mapping exists between the two areas to demonstrate that the Montebello sandstones grade laterally into the Chaneysville siltstones. Furthermore, as Kaiser (1972, Figure 57) shows, sediment was entering the depositional basin from more than one source, and the Chaneysville siltstone may represent deposition in another distinct lobe of the Mahantango delta.

The Tully Limestone has traditionally overlain the Hamilton Group (Mahantango Formation) since the name was first definitively brought into central Pennsylvania. Butts (1918) placed it in the top of his Hamilton Formation (Figure 2) but felt it probably belonged in the Upper Devonian. Willard (1935) revised the nomenclature by introducing the Rush Formation, placing the Tully above the Mahantango Formation (Figure 2). Dyson (1963) reverted to Butts' terminology, but included the Tully in the Harrell. Although the Tully Limestone attains a large thickness (up to 270 feet, or 82 m) in the northern Valley and Ridge province in the vicinity of Williamsport (Faill and others, 1977), in the lower Susquehanna and Juniata valleys it is a thin calcareous shale, with at most one or two limestone beds or layers of limestone nodules. In this area it is lithically and faunally similar to the

shales of the Sherman Ridge Member, a fact recognized by Dyson (1963). Ellison (1965, p. 38) notes that in portions of the area it is overlain and underlain by faunas regarded as "Hamilton." Its contact is conformable and gradational with the underlying Sherman Ridge, and there is no evidence of the discontinuity or erosion at its base that is characteristic of it in New York (Heckel, 1969). In contrast, the Tully is distinct from the overlying Burket, both lithically and faunally. Therefore the Tully is herein placed as the uppermost member of the Mahantango.

In summary, most of the Middle Devonian rocks in central Pennsylvania are assigned to the Mahantango Formation (Figure 2).

From the most recent mapping in central Pennsylvania (Faill and Wells, 1974; Hoskins, 1976), it became apparent that, although rather disparate lithologies exist within the Mahantango Formation, these various lithic types are related environmentally to one another by an overriding sedimentologic feature—the upward-coarsening cycle. Thus, it is not only the presence of dark-gray shale, gray siltstones, and sandstones that warrants inclusion in the Mahantango, it is the organization of these lithic types into upward-coarsening cycles. This sedimentologic pattern pervades the Mahantango Formation, regardless of location in central Pennsylvania, maximum grain size, or thickness of the cycles. Recognition of these cycles forms the basis of this revised stratigraphic nomenclature, which provides for accurate and detailed mapping of the Middle Devonian rocks in central Pennsylvania.

The Onondaga and Marcellus Formations are lithically distinct and are retained in their original usage. The six members of the Mahantango (the Turkey Ridge, Dalmatia, Fisher Ridge, Montebello, Sherman Ridge, and Tully Members) represent separately mappable lithic units (except for the Tully in south-central Pennsylvania), and constitute the various three-dimensional parts of the Mahantango delta. Variations of lithic and stratigraphic sequence from place to place merely reflect different locations within the delta complex, both vertically and laterally.

DETAILED MIDDLE DEVONIAN STRATIGRAPHY

ONONDAGA FORMATION, SELINSGROVE MEMBER

The Onondaga Formation has two members, the Needmore Shale of Willard and others (1939) at the base and the Selinsgrove Limestone of White (1883) at the top, both of which do not change appreciably across central Pennsylvania in terms of lithic composition. The Lower-Middle Devonian boundary is placed at the contact between the two members (Oliver and others, 1969).

The Selinsgrove Member consists of approximately 100 feet (30 m) of medium- to dark-gray, thin- to thick-bedded, fossiliferous, argillaceous limestone (Faill and Wells, 1974).

The contact of the Onondaga Formation with the overlying Marcellus Formation is conformable and sharp, being occupied by up to 6 feet (2 m) of the Tioga metabentonite. This change from carbonate to clastic sedimentation marks the beginning of a thick terrigenous deposition that was to persist throughout the remainder of the Paleozoic. The Middle Devonian sequences (Marcellus and Mahantango) represent the first "event" of this clastic deposition.

MARCELLUS FORMATION

The Marcellus Formation consists of black to very dark gray, uniform, laminated, carbonaceous, noncalcareous, fissile shale, approximately 100 feet (30 m) thick (Faill and Wells, 1974).

Thin, discontinuous sandstone bodies that are lithically similar to the Turkey Ridge occur within the Marcellus in a limited area. South of Dalmatia, a 25-foot- (8-m-) thick sandstone occurs at the base of the Marcellus, lying directly on the Onondaga limestone beds. However, this sandstone is not present at Cocolamus Creek or further west. Near Shadle, an approximately 25-foot- (7-m-) thick sandstone, also lithically similar to the Turkey Ridge, occurs some 30 feet (10 m) above the base of the formation. Several thin sandstones occur within the Marcellus in exposures at West Mahantango Creek and south of Dalmatia, but elsewhere in this area these sandstones are either absent or not exposed. The sandstones probably represent distributary channels that provided the first coarse sediments to the Mahantango delta.

At Selinsgrove Junction, an argillaceous limestone approximately 30 feet (10 m) thick occurs some 300 feet (90 m) above the base of the Marcellus, and has been called the "Selinsgrove upper limestone" by White (1883). A similar limestone is also present along Penn's Creek west of Sunbury, and near Shadle. Limestone also occurs at Dalmatia approximately 500 feet (150 m) above the base of the Marcellus. A thin limestone and calcareous claystone sequence has been recorded by Dennison and Hoskins (personal communication) in the Marcellus in exposures along the Allegheny Front and in Fulton County near Warfordsburg, and was reported by Lytle and others (1963, p. 25) from gas wells in the Purcell field of Bedford County.

MAHANTANGO FORMATION

The Mahantango Formation forms the remainder of the Middle Devonian in central Pennsylvania; it consists of shales, silty claystones, siltstones, sandstones, and conglomeratic sandstones, and has a thin calcareous interval at the top that represents the Tully Limestone. The distinctive sedimentologic feature of this formation is the upward-coarsening cycle, a pattern that pervades virtually the entire formation (Faill and Wells, 1970; Kaiser, 1972). A cycle characteristically begins with dark-gray to olive-gray

claystone or shale and successively coarsens upward to olive-gray siltstones, light-olive-gray siliceous sandstone, and fine- to medium-grained, fossiliferous, locally conglomeratic sandstones. The contacts between successive cycles are sharp, consisting of an abrupt change in grain size from a sandstone to a claystone or silty shale. The upward increase in grain size within cycles is generally gradual, although small abrupt changes occur. The cycles range in thickness from 6 to 250 feet (2 to 75 m), the thinner cycles occurring predominantly in the coarser grained sequences and the thicker cycles in the finer grained sequences.

In addition to the vertical variation in grain size, the maximum grain size within a single cycle tends to decrease laterally away from the basin center. Each cycle becomes progressively finer grained throughout to the north and west. With most cycles, the coarser grained beds become progressively finer grained laterally until they are indistinguishable from the lower part of the same cycle or the overlying cycle. The thicker cycles extend for as little as 5 miles (8 km) and as much as 30 miles (50 km). The thinner cycles presumably do not extend as far.

Systematic variation in the maximum grain size in the cycles enables a division of the Mahantango Formation into six mappable or lithologically distinct members: the Turkey Ridge, Dalmatia, Fisher Ridge, Montebello, Sherman Ridge, and Tully (Plate 1). In general, the majority of those cycles that possess a maximum grain size of fine sand or larger occur in the middle of the formation and comprise the Montebello Member. These sandstones are thicker bedded and more common than in other cycles. The only other sandstones that approach the Montebello in coarseness are the fine- to medium-grained Turkey Ridge sandstone at the base of the formation; the medium- to coarse-grained sandstones of the Dalmatia Member, which overlies the Turkey Ridge; and two Sherman Ridge cycles in the southern part of the area. The finer grained cycles occur predominantly between the Turkey Ridge or Dalmatia and the Montebello, and between the Montebello and Tully (or the Sherman Ridge Member in the central and northern area). The coarse-grained layers of the Montebello cycles underlie second-order ridges locally called mountains. The Turkey Ridge, Dalmatia, and Sherman Ridge cycles underlie distinctly lower ridges.

The total thickness of the Mahantango Formation ranges from 1,700 to 2,050 feet (520 to 625 m), but the thicknesses of individual members exhibit a much greater variability, principally because of the great lateral changes of the cycles within the formation. Thus the lithologic sequence in the Mahantango varies from place to place. As a consequence, the sequence of members also varies, so that some members are correlative with parts of other members, as discussed at further length in the Synopsis.

Turkey Ridge Member

Where it exists, the Turkey Ridge Member occupies the base of the Mahantango Formation. It consists of light- to medium-olive-gray,

medium- to thick-bedded, planar-bedded, uniform, fine- to medium-grained sandstone. The profound lithic uniformity of the beds, which generally lack internal structures, is reflected in its typical spheroidal exfoliation pattern. This member is distinct from the other members in that it is the only one that does not exhibit an upward-coarsening cyclic pattern—its contact with the underlying Marcellus is generally sharp, consisting of an abrupt change from black laminated shales to fine-grained sandstone. However, its lithic similarity with the other Mahantango sandstones is deemed sufficient for its inclusion in the formation.

The thickness of the Turkey Ridge averages approximately 90 feet (30 m) over much of the area. To the north and west, it becomes progressively less sandy, finer grained, and thinner bedded, and the sandstones grade laterally into siltstones and dark-gray shales (Plate 1). Miller (1961) assumed that the Turkey Ridge became thicker to the south and passed laterally into the Montebello Member. However, the Turkey Ridge and Montebello apparently to not merge (at least within the present outcrop area), because at Rockville a sandstone lithically similar to the Turkey Ridge (and perhaps correlative) is overlain by a 127-foot- (39-m-) thick dark-gray shale, and the sandstone and shale both underlie the Montebello. It is not known whether the shale is the lower part of the Dalmatia cycle (the sand part of which would be merged with the Montebello) or the Fisher Ridge Member (in which case the lower sandstone would be Dalmatia and not Turkey Ridge). The lower sandstone was called the Fort Hunter Sandstone by Willard and others (1939), but it has never been traced away from this single outcrop, and thus the name Fort Hunter is formally abandoned.

Dalmatia Member

The Dalmatia Member of the Mahantango Formation is herein defined as the shale, siltstone, and sandstone sequence above the Turkey Ridge Member and below the Fisher Ridge Member. Its type section is in an abandoned quarry along the Penn Central railroad tracks 2 miles (3.2 km) south of Dalmatia, Northumberland County (see Appendix 1).

Where it occurs, the Dalmatia Member directly overlies the Turkey Ridge Member. It appears to be the lowest upward-coarsening cycle within the Mahantango, with dark-olive-gray silty shales at the base and an upward increase in grain size to a light-olive- to dark-gray, medium-bedded, planar-bedded, medium-grained sandstone. Within the major cycle are at least two subcycles. In the coarsest beds, scattered coarse and very coarse quartz grains are occasionally present, as well as a number of shale pebbles. In contrast to the nonfossiliferous Turkey Ridge sandstones, the coarser Dalmatia contains rare brachiopod shells; *Styliolina* also occurs in limy layers near the base of, and within, the upper thickly bedded, sandy portion of the cycle.

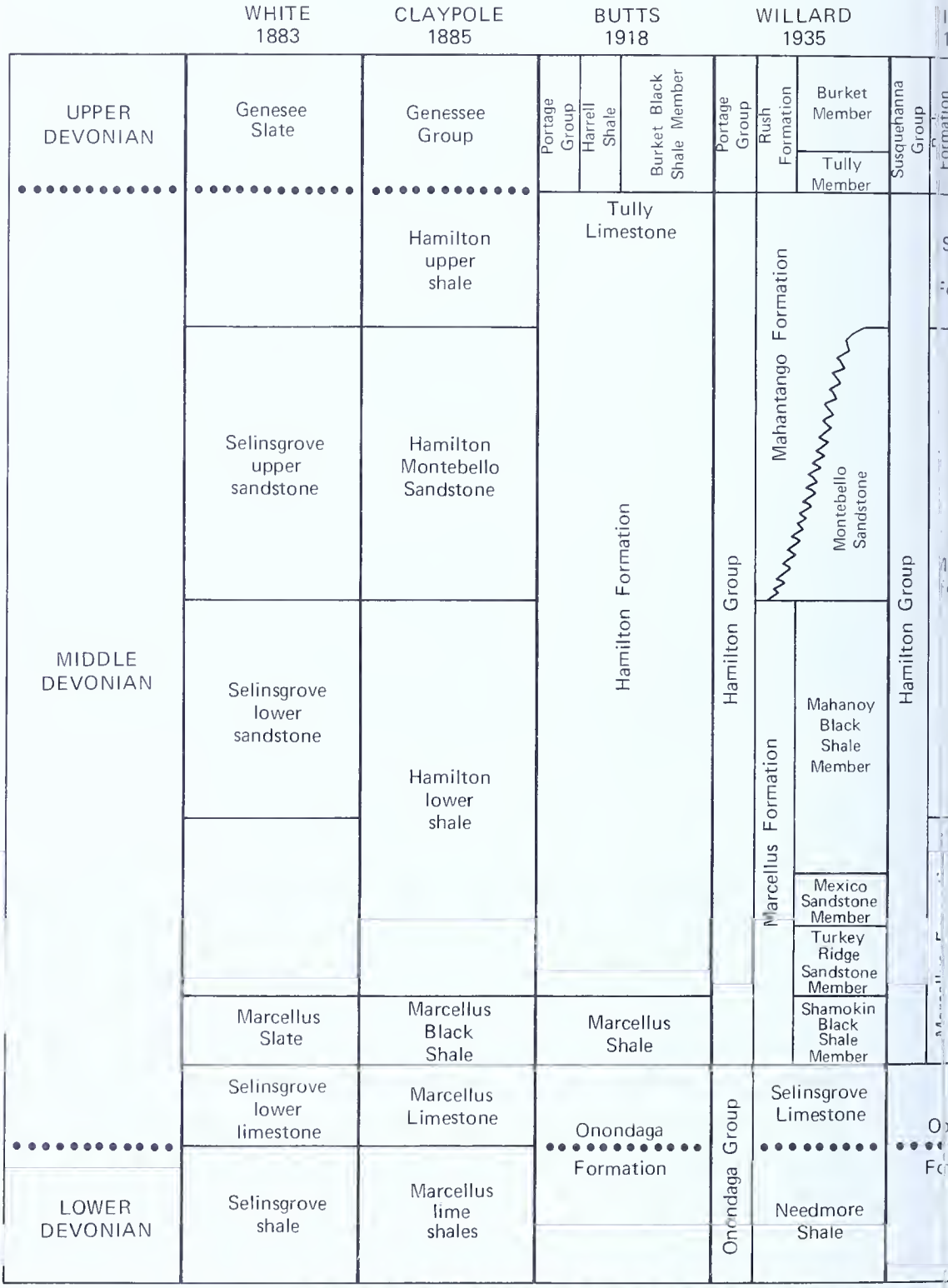
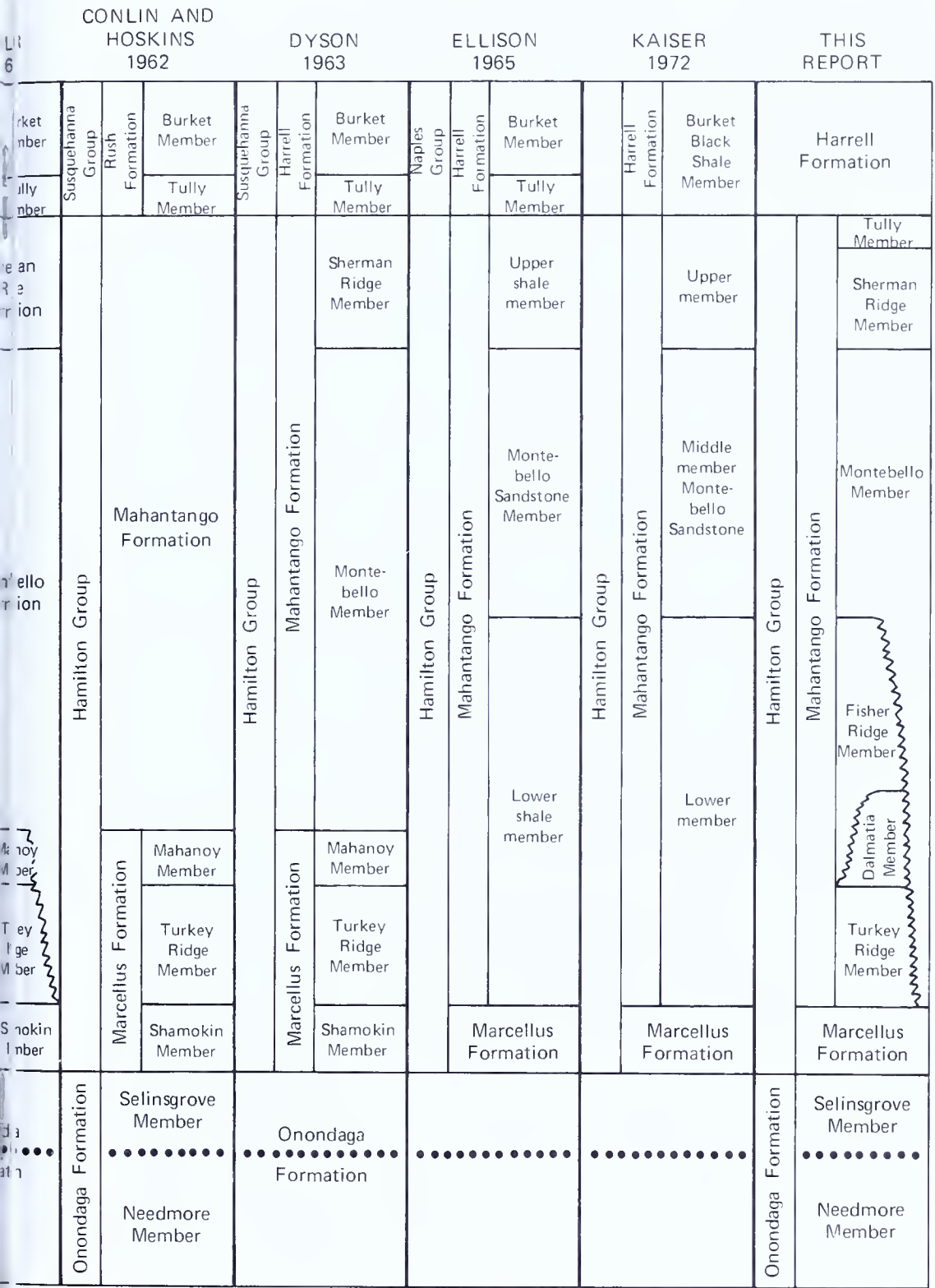


Figure 2. Correlation chart of Middle Devonian strata past 95 years in central Pennsylvania. See text



pic units, illustrating the change in nomenclature over the
discussion.

The Dalmatia Member possesses a maximum thickness of 300 feet (90 m) at Dalmatia. To the north and west, this member becomes progressively finer grained and thinner bedded, laterally passing into the lower part of the Fisher Ridge Member. To the south, lack of exposure of the Dalmatia obscures its nature and relation to the rest of the Mahantango.

Fisher Ridge Member

The Fisher Ridge Member of the Mahantango Formation is herein defined as the shale and siltstone sequence underlying the Montebello Member and overlying the Dalmatia Member (or the Marcellus Formation where the Dalmatia and Turkey Ridge are absent). Its type section is along the Penn Central railroad tracks at the western end of Fisher Ridge, Northumberland County and is described in Appendix 2. The Fisher Ridge consists of a rather uniform sequence of interbedded medium-olive-gray shale and medium- to olive-gray, laminated, shaly siltstone.

The Fisher Ridge Member is quite variable in thickness. It varies from 127 feet (39 m) in the south (at Rockville) to 900 feet (300 m) in the north where the Turkey Ridge and Dalmatia Members are absent and the Montebello is thinnest.

The Fisher Ridge is the lower part of a very thick, complex cycle, the upper part of which consists of the lower sandstones of the Montebello Member. The Fisher Ridge contains random, minor cycles having silt as the maximum grain size. In spite of the fact that it is only part of a major cycle, its great thickness over much of this area and its uniform fine-grained character in contrast to the overlying Montebello and underlying Dalmatia-Turkey Ridge enable it to be easily mapped, and thus justify its status as a formal member.

Montebello Member

The Montebello Member represents the coarsest, most complex development of cycles in the Mahantango Formation. The characteristic cycle in the Montebello consists of medium- to dark-gray, thick- to massive-bedded shaly siltstones at the base, which coarsen upward (often with sharp, discontinuous changes in grain size) to medium-light-gray, medium- to very thick bedded, fine- to medium-grained, siliceous sandstones. In a few of the cycles, the maximum grain size is locally coarse- and very coarse grained sandstone, conglomeratic sandstone, and in the south, even conglomerate. The coarsest beds are frequently fossiliferous, containing thick-shelled brachiopods, molluscs, and crinoids, both scattered throughout the bed and concentrated in lenses.

The cycles in the Montebello, in addition to being coarser grained, are generally thinner than in other members of the Mahantango. The major

cycles are up to 300 feet (90 m) thick, but usually consist of a sequence of thinner cycles 15 to 150 feet (5 to 50 m) thick, which become progressively coarser grained upward through the major cycle. These nested cycles apparently represent minor fluctuations within a larger cyclic event.

Throughout the Millerstown and Millersburg quadrangles the Montebello consists of two major cycles. (Actually, the lower finer grained portion of the lower cycle is mapped as the Fisher Ridge Member. The upper, sandy portion and the complete overlying cycle are in the Montebello.) These two sandstone sequences form a prominent double-crested ridge or double set of riffles in river beds. To the south, the Montebello contains an additional lower cycle, forming a triple-crested ridge. To the west and north in the Mifflintown and Sunbury quadrangles, the Montebello ridge is single crested, reflecting the diminution of grain size and bed thickness of the two lower major cycles.

The thickness of the Montebello varies from a maximum of 1,100 feet (335 m) in the south to 150 feet (50 m) in the north. Most of this thinning represents a northward decrease in grain size in the lower and middle portions of the member, represented by a northward passing of Montebello beds into the Fisher Ridge lithology.

As discussed above, the contact of the Montebello with the underlying Fisher Ridge Member is very gradational, both vertically and laterally. In contrast, the contact of the Montebello with the overlying Sherman Ridge Member is very sharp, consisting of an abrupt decrease (within less than 3 inches, or 8 cm) from coarse-grained quartzite to shale or silty shale.

Sherman Ridge Member

The Sherman Ridge Member is regionally the most uniform member of the Mahantango Formation. Over much of the area the Sherman Ridge consists of two upward-coarsening cycles, overlain by a third, probably incomplete cycle. The bulk of each of the three cycles is medium-olive-gray massive-bedded fossiliferous silty claystone. In the upper portion of the two complete cycles, the grain size gradationally increases toward the top to siltstone or fine-grained sandstone. In the Loysville quadrangle and at Girtys Notch and Amity Hall, the lowest Sherman Ridge cycle culminates in a fossiliferous "oolitic" (chamosite) hematitic layer. As with cycles in the other members, the maximum grain size progressively decreases to the north.

The thickness of the Sherman Ridge Member is quite uniform over the area, averaging 600 feet (200 m). Each of the two complete cycles is approximately 250 feet (80 m) thick.

The contact with the overlying Tully Member is gradational, consisting of a gradual increase in the carbonate content of the shale beds and an increasing amount of fossils.

Tully Member

The Tully Member is rarely exposed in this area because of its thinness and its low resistance to weathering and erosion. It consists of up to 20 feet (6 m) of olive-gray to medium-gray, calcareous, fossiliferous shale, overlain by 1 foot (0.3 m) of shaly, fossiliferous limestone (Dyson, 1963). Layers of limestone nodules may also occur in the shales. To the north, in the Williamsport area, the Tully is much thicker (up to 270 feet, or 82 m) and is a thin- to medium-bedded, argillaceous limestone in its upper part, and dark-gray calcareous silty shale in its lower part (Faill and others, 1977). Significantly, one or two intervals of calcareous shales occur in the upper part of the Mahantango in that area that are essentially identical to the lower part of the Tully. This indicates that the Tully is probably a calcareous facies of the Mahantango depositional basin, and not a distinct sedimentologic unit that developed subsequent to the Mahantango deposition. The profound lithic break is between the Tully carbonates and the black shales of the overlying Harrell Formation.

SYNOPSIS OF MAHANTANGO STRATIGRAPHY

The Mahantango complex of upward-coarsening cycles represents a period of delta building in central Pennsylvania throughout most of Middle Devonian time (Kaiser, 1972; Faill and Wells, 1970, 1974). The predominance of sandstones in the southern sections as compared with those to the north indicates that the source of sediments was to the southwest of Harrisburg, and that the delta was built northward from this shoreline. The absence of sandstones in sections radially to the northeast, north, and west indicates that this delta was a relatively small accumulation within the Appalachian geosyncline; yet the influence of increased sediment input was felt across the entire basin, as indicated by the regional cessation of Onondaga carbonate sedimentation and initiation of Marcellus shale deposition.

The Onondaga is recognized basin-wide and represents a time of relatively little sediment input except in Pennsylvania and to the south, where considerable mud was deposited. The commencement of the Marcellus black carbonaceous shale deposition, also recognized across the entire basin, heralded a profound change to terrigenous deposition. With the exception of thin, local deposits of sandstone representing minor distribution channels, the sediment deposited was very fine and contained considerable carbonaceous material. The presence of the "Selinsgrove upper limestone" in the Marcellus represents a brief, open marine environment that interrupted an otherwise uniform black shale deposition.

The Turkey Ridge sandstone is the first major sandstone deposit to spread over the southern basin floor. The abrupt increase in grain size,

anomalous with respect to the rest of the Mahantango units, apparently represents a sudden increase in detrital material that spread northward for 40 miles (65 km), becoming finer grained and thinner with increasing distance from the source. The absence of fossils, the uniformity of bedding, and the lack of upward-coarsening cyclicity within the Turkey Ridge also contrasts with the remainder of the Mahantango. The lateral equivalents of the Turkey Ridge beyond its area of occurrence are in question (Plate 1). Because the Marcellus thickens radially from the source area, the Turkey Ridge probably grades laterally into a Marcellus lithology, rather than a Fisher Ridge lithology.

The overlying Dalmatia Member is the first recognizable upward-coarsening cycle in the Mahantango sequence. The vertical increase in grain size from fine siltstone to conglomeratic sandstone distinguishes it from the Turkey Ridge, even though it has approximately the same areal distribution and usually underlies the same topographic ridge. The lateral equivalent of the Dalmatia beyond its area of occurrence is probably the Fisher Ridge Member, because it appears to grade radially to olive-gray silty shale.

The Montebello attains its greatest thickness in the south near Harrisburg, and consists of three major cycles. Radially from this point, the Montebello thins by lateral gradation of the lower part into a Fisher Ridge interbedded shale and siltstone sequence, representing a decrease in grain size away from the input source. Northward, only the upper two cycles and then the uppermost cycle persist, and the grain size decreases gradually as the distance from the source area increases. At Bloomsburg (White, 1883) and Williamsport (Faill and others, 1977), there is very little sandstone in the Mahantango. To the west, at Mt. Union (White, 1885; Ellison, 1965), some siltstones occur in the middle of the Mahantango, but they are quite thin.

The Fisher Ridge Member represents the lateral extension of the lower Montebello delta sandstones, and progressively replaces the Montebello to the north and west. Because it is the lower portion of the large cycle that culminates in the Montebello sandstones, its contact with the Montebello is gradational. Some minor cyclicity occurs within it, reflecting the sandstone cycles that are laterally equivalent to the south. Further to the north and west, however, this minor cyclicity fades and the unit is a rather uniform, olive-gray, silty shale.

The development of the Middle Devonian Mahantango delta seems to have reached its apex in the uppermost Montebello sandstones, for these beds are the coarsest grained in the formation, and possess the greatest lateral extent. The sediment input into this area apparently decreased abruptly, because the bulk of the rocks of the overlying Sherman Ridge Member are shales and siltstones. However, two influxes of sediment occurred, producing two upward-coarsening cycles within the Sherman Ridge, although the grain size and lateral extent nowhere match those of the upper Montebello sandstones.

Subsequent to these two Sherman Ridge cycles, the terrigenous sedimentation decreased further; marine animal life became more abundant, and limestone began to form, as indicated by the increased calcareous content and fossils and by the southward encroachment of Tully deposition. The faunal and lithic similarity between the Sherman Ridge shales and the Tully calcareous shales and argillaceous limestones suggests that the Tully is a lateral carbonate facies of the Mahantango delta.

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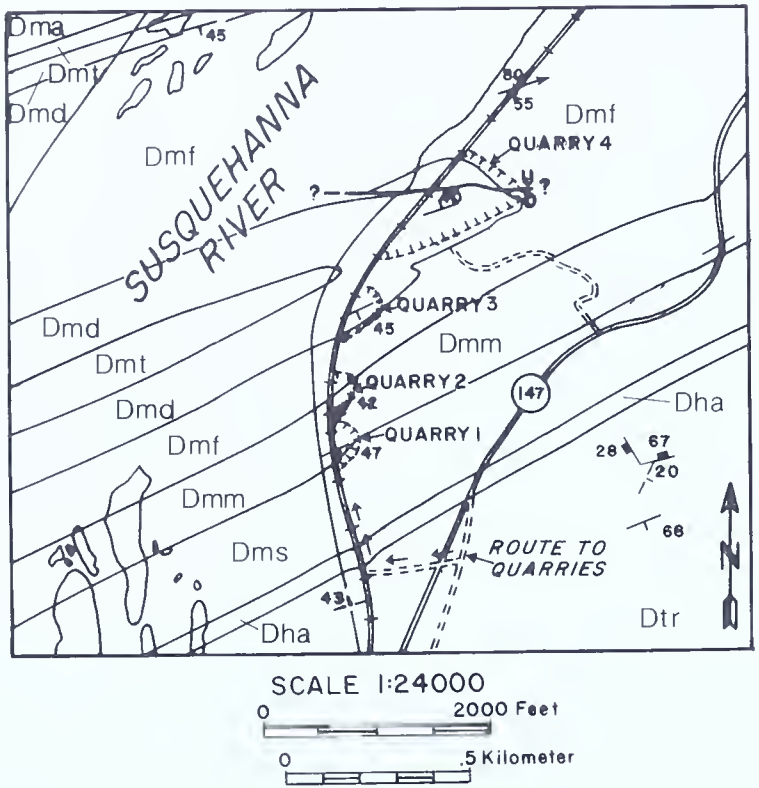


EXPLANATION

Trimmers Rock Formation	Dtr
Harrell Formation	Dha
Mahantango Formation	
Sherman Ridge Member	Dms
Montebello Member	Dmm
Fisher Ridge Member	Dmf
Dalmatia Member	Dmd
Turkey Ridge Member	Dmt
Marcellus Formation	Dma

Figure 3. Geologic map of the vicinity surrounding the measured sections in the Dalmatia quarries.

APPENDICES

APPENDIX 1. TYPE SECTION OF THE DALMATIA MEMBER OF THE MAHANTANGO FORMATION

The section was measured by D. M. Hoskins along the north wall of a quarry 2 miles (3.2 km) south of Dalmatia, Pennsylvania, along the east side of the Penn Central Railroad. The quarry is the third of four (Figure 3), counting from the south, which expose most of the Mahantango Formation. The section in Appendix 2, which ends at the south wall of quarry no. 3, describes rocks of the Montebello and Fisher Ridge Members and the upper part of the Dalmatia Member of the Mahantango Formation, units that lie immediately above the present section.

Units 28-20 were measured in quarry no. 3. Units 19-1 were measured on the wooded hillslope above the quarry.

The section is located at 40°37′48″N/76°56′02″W.

Unit	*Lithology*	*Thickness (feet)*	*(inches)*
	Mahantango Formation, Dalmatia Member (220 feet 4 inches (67 m) exposed)		
28	Sandstone, very fine grained, medium-light-gray; bedding distinct.	12	
27	Sandstone, fine- to medium-grained with scattered coarse grains, medium-light-gray, very calcareous; weathers to moderate-yellowish-brown.	1	3
26	Sandstone, fine- to medium-grained, light-gray, calcareous, discontinuous, very thin (1/16 to 1/14 in.), shaly, carbonaceous, laminated with laminae from 1/4 to 1 in. Units 27 and 26 grade laterally into each other and form one larger unit.	1	
25	Sandstone, very fine to fine-grained, medium-dark- to medium-gray; well-developed spheroidal weathering; bedding from 2 to 7 ft thick; surfaces undulatory.	14	
24	Sandstone, fine-grained, medium-gray, calcareous; middle portion of unit contains discontinuous laminae which appear to be carbonaceous.	2	2
23	Interbedded claystone, grayish-black to dark-gray, shaly, pyritic, and limestone, very fine grained, dark-gray, in discontinuous nodules which compose at least 50 percent of layer; claystone encloses nodules.		11
22	Claystone, silty, dark-gray; bedding is shaly.		7
21	Limestone, very fine grained, medium-gray, clayey, pyritic; at top is 5 in. of very fine grained, medium- to medium-light-gray, silty, laminated, very calcareous sandstone containing a few limestone nodules up to 6 in. long and 2 in. high; limestone contains some brachiopods; units 21-23 are covered with lichen, which has apparently produced a surface mineralization of a sulfate mineral.	1	

20	Siltstone, dark- to medium-dark-gray, very finely sandy, laminated, very shaly; upper 2 ft calcareous; few 3- by 1½-in. limestone nodules in upper 1 ft; parts covered with lichen and sulfate mineral; contains weakly calcareous zones. Unit is similar in surface appearance to the Marcellus Formation of the Loysville and Mifflintown quadrangles.	68	
19	Covered.	27	
18	Sandstone, very fine grained, medium-dark-gray, silty; mostly shaly, sandy beds ⅛ to 1 in. thick, averaging ¼ in.; contains a 3-ft by 11-in., very calcareous, medium-light-gray, laminated and very finely sandy nodule 5 ft from base.	23	
17	Limestone, very fine grained, medium-light-gray with slightly bluish cast, sandy; upper half in beds ¼ in. thick; one bed has laminae weathering out; fossiliferous with *Styliolina* in lower half.	1	8
16	Sandstone, very fine grained, medium-dark-gray, silty, well-laminated, shaly; sandy beds average ¼ in. in thickness; nearly identical to unit 18.	29	
15	Sandstone, fine-grained, medium-gray, laminated.		6
14	Sandstone, very fine grained, medium-gray, unlaminated.		7
13	Sandstone, very fine grained, medium-dark- to medium-light-gray, laminated; portions shaly; sandy beds average ½ to 1 in. thick; dark laminae increase toward base and become thicker, up to 1/16 in.	12	
12	Sandstone, fine-grained, dark-gray; bedding ½ to 4 in. thick, averaging 2 in.; laminae poorly developed.	3	
11	Sandstone, fine-grained, dark-gray, in ¼-in.-thick beds.	1	
10	Sandstone, very fine grained, medium-gray, silty.		2
9	Sandstone, fine-grained, medium-dark-gray, laminated.	2	5
8	Covered. Probably same as unit 7.		6
7	Sandstone, very fine grained, medium-gray, laminated, shaly; well-bedded in beds from ¼ to ½ in. thick, averaging ¼ in.	6	6
6	Claystone, medium-light-gray, weathering to light-gray.		1
5	Interbedded siltstone, medium-light-gray, unlaminated, and sandstone, very fine grained, laminated, shaly; somewhat hackly weathering.	3	2
4	Sandstone, very fine grained, medium-gray, pyritic; channel filling or flow roll; well-developed jointing; base undulatory.	1	6
3	Interbedded very fine grained, silty sandstone, medium-gray, and clayey siltstone, medium-gray; unit shaly with hackly weathering; sandstone discontinuous and somewhat nodular.	3	6
2	Sandstone, very fine grained, medium-dark-gray; spheroidal weathering; bedding not apparent; seems to be channel or flow-roll sandstone having a lens shape; pinches out within 25 ft.	2	4
1	Claystone, dark-gray, shaly; some interbeds of very fine grained, laminated sandstone.	1	6
	Total exposed	220	4
		(67 m)	

APPENDIX 2. TYPE SECTION OF THE FISHER RIDGE MEMBER OF THE MAHANTANGO FORMATION, INCLUDING DESCRIBED SECTION OF THE MONTEBELLO MEMBER AND PARTS OF THE SHERMAN RIDGE AND DALMATIA MEMBERS

The section was measured by D. M. Hoskins in two quarries and on quarry access roads 2.5 miles (4 km) south of Dalmatia, along the east side of the Penn Central Railroad near mile post 121. The quarries are the first and second, counting from the south, of four quarries in the immediate area (see Figure 3). The section in Appendix 1 continues the stratigraphic sequence below the present description, which ends at the south edge of quarry no. 3.

The lower part of the Sherman Ridge Member and the upper part of the Montebello Member are exposed in quarry no. 1; the lower part of the Montebello Member and the upper part of the Fisher Ridge Member are exposed in quarry no. 2. The lower part of the Fisher Ridge Member and the upper part of the Dalmatia Member are exposed on the hillslopes north of quarry no. 2 in a series of access roads leading from the former working level to the tops of the quarries.

The Sherman Ridge Member and the upper part of the Montebello Member through unit 67 were measured at the top of the quarry rather than at the working face because of the danger of the highwall. Units 66-54 occur in quarry no. 1; units 53-52 on a small spur between quarries no. 1 and no. 2; and units 51-31 occur in quarry no. 2, as do units 30-28 of the Fisher Ridge Member. The top of the section is located 40°37′42″N/76°56′06″W.

Unit	*Lithology*	*Thickness (feet)*	*(inches)*
	Mahantango Formation, Sherman Ridge Member (50 feet 8 inches (15 m) exposed)		
109	Claystone, light-olive-gray; spheroidal and hackly weathering; occasional fossils scattered throughout, mainly crinoid columnals, brachiopods, small pelecypods, and gastropods.	11	8
108	Sandstone, very fine grained, dusky-yellow, laminated.		2
107	Claystone, light-olive-gray, hackly and spheroidal weathering; scattered fossils and occasional fossil concentrations in thin beds. Trilobites occur in bands 13.5 and 17 ft from top. Unit becomes clayey in lower few feet.	35	
106	Claystone, weathered from grayish yellow to dusky yellow, laminated; many ostracodes; 4 in. from top is 1-in. white clay zone containing brachiopods.	1	2
105	Claystone, moderate-brown; hematitic.		6
104	Sandstone, very clayey and friable; small amount of hematite in middle; weathers to dark yellowish orange.	1	2
103	Claystone, hematitic, weathered moderate brown.		4

Unit	Lithology	Thickness (feet)	Thickness (inches)
102	Sandstone, fine- to medium-grained, very light gray, very clayey and friable.		8
	Montebello Member *(378 feet 10 inches (117 m) total thickness)*		
101	Sandstone, coarse- to very coarse-grained, very light gray, hematitic; weathers to dark yellowish orange.		8
100	Sandstone, medium- to coarse-grained, very light gray.	1	6
99	Sandstone, very coarse grained and conglomeratic; very light gray; largest pebbles ½ in. long; weathers to dark yellowish orange.		8
98	Sandstone, medium- to coarse-grained, very light gray; contains a few large brachiopods (genus *Mediospirifer*).	3	4
97	Sandstone, coarse- to very coarse-grained, very light gray, fossiliferous (*Mediospirifer*).	2	7
96	Sandstone, fine- to medium-grained, very light gray; brachiopods.	4	
95	Sandstone, coarse- to very coarse grained with scattered granules, very light gray.		4
94	Sandstone, fine-grained, light-olive-gray; outer surface has weathering rinds.		10
93	Sandstone, very fine grained and silty, yellowish-gray; weathering rinds; upper 1 in. hematitic.	19	10
92	Sandstone, coarse- to very coarse grained, very light gray.		2
91	Sandstone, fine-grained, light gray.		6
90	Sandstone, medium-grained, very light gray, very fossiliferous and friable; contains large number of tubes of unknown origin; lower portion hematitic, weathering to light brown and grayish red.		6
89	Sandstone, medium-grained, very light gray; a few fossils.		10
88	Sandstone, coarse- to very coarse grained, friable; contains brachiopods, some tubes; weathers grayish red.	1	9
87	Sandstone, fine-grained, very light gray.	2	
86	Sandstone, coarse-grained, very light gray.	1	2
85	Sandstone, medium- to coarse- to very coarse grained, very light gray; grain size decreases upward by grading.	7	6
84	Sandstone, medium-grained, very light gray; weathering rinds in some beds; 3-in. lens of very coarse grained sandstone in middle.		8
83	Sandstone; grades from medium to coarse grained at bottom; bed thins to 4 in.	8	4
82	Sandstone, fine- to medium-grained, very light gray; weathering rinds.	1	3
81	Sandstone, very coarse grained and conglomeratic, very light gray; pebbles up to ⅜ in.; fossiliferous (large brachiopods).		9
80	Sandstone, grading from medium to very coarse grained in bottom 1 in., very light gray.	1	7
79	Sandstone, fine- to medium-grained, very light gray, very friable, slightly shaly.		3
78	Sandstone, medium-grained, very light gray.	1	7

Unit	Lithology	Thickness (feet)	Thickness (inches)
77	Sandstone, coarse-grained, very light gray; weathers to yellowish gray.	1	2
76	Sandstone, medium-grained, very light gray; weathering rinds.		10
75	Sandstone, grading from coarse to very coarse grained at base, very light gray.	1	6
74	Sandstone, grading from medium to very coarse grained with some pebbles up to ¾ in., very light gray.		11
73	Sandstone, medium-grained, very light gray, very friable; weathering rinds; bedding ⅛ to ½ in. in thickness; weathers to dusky yellow.	1	4
72	Sandstone, very coarse grained, very light gray, friable.		4
71	Sandstone, fine-grained, yellowish-gray; lower 7 ft exhibits weathering rinds and incipient spheroidal weathering; coarse grained at base.	9	
70	Sandstone, fine-grained, yellowish-gray; bedding from 2 to 12 in.	15	9
69	Sandstone, fine- to medium-grained, very light gray; some fossils; bedding 1 to 2 ft in thickness.	8	8
68	Sandstone, fine- to medium-grained, light-gray to yellowish-gray, laminated.	39	4
67	Sandstone, fine-grained, light-olive-gray in two prominent beds 7 and 11 in. thick.	1	6
66	Sandstone, very fine to fine-grained, medium-light-gray. Bedding averages 1 to 2 in. in thickness; laminated with shaly laminae.	27	11
65	Sandstone, fine- to medium-grained, medium-light-gray; bedded in three nearly equally thick beds having incipient spheroidal fractures.	7	4
	Units 66 and 65 are faulted by a reverse fault that dips 70° and has 3 ft of displacement.		
64	Siltstone, dark-gray, sandy, laminated; occasional bands of very fine to fine-grained sandstone; bedding averages 2 ft in thickness; basal 3 ft contains a few 1-in. sandstone beds.	32	7
63	Sandstone, very fine to fine-grained, medium-light-gray with bluish cast; weathers light-olive-gray; bedding 6 in. to 4 ft; weathered to conchoidal surface; top has lens-shaped fossil zone containing *Tentaculites* and *Mucrospirifer*.	11	8
62	Sandstone, very fine to fine-grained, medium-gray, finely laminated, crossbedded in beds averaging 1 to 2 in. in thickness; weathers shaly; bedding surfaces ripple marked.	1	4
61	Sandstone, very fine to fine-grained, medium-gray; weathers to light olive gray; in one bed, tending to break down to smaller indistinct and discontinuous beds.	2	8
60	Sandstone, very fine grained, medium-gray, laminated, shaly with some silty layers; weathers from medium gray to olive gray; bedding 1 to 4 in. thick; portions of surface have conchoidal fracture.	24	8
59	Siltstone, finely laminated, dark-gray, shaly.		9
58	Interbedded siltstone and very fine grained, medium-gray sandstone; sandy beds 1 to 3 in. thick in lower parts.	3	7

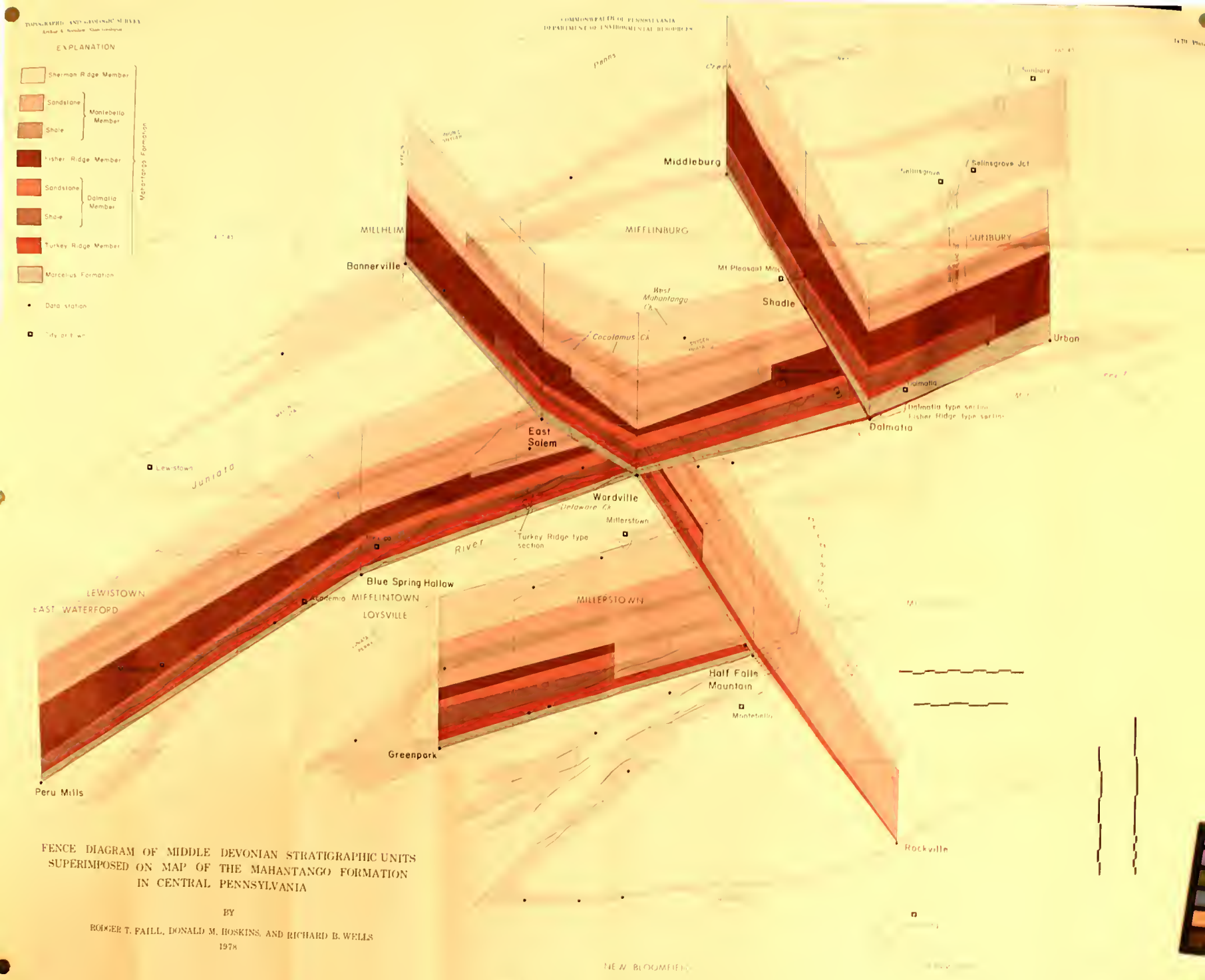
Unit	Lithology	Thickness (feet)	Thickness (inches)
57	Sandstone, fine-grained, medium-gray; a few muddy laminae; prominently jointed. This unit used to bridge two 90-degree cross-cutting faults that displace units 53-58.	4	2
56	Siltstone, finely laminated, dark-gray, shaly; conchoidal weathering on bedding surface.	4	2
55	Sandstone, very fine to fine-grained with silty laminae ¼ in. apart, medium-dark-gray, prominently jointed; fractures only on joint surfaces.		11
54	Claystone, silty, between medium gray and dark bluish gray, ferruginous on jointed surfaces.	4	8
53	Siltstone grading down to very fine grained sandstone, medium-dark-gray.	2	3
52	Sandstone, fine- to medium-grained, light- to medium-gray; brachiopods; bedding 1 to 3 ft thick; forms a prominent riffle in river bed. Top of Lower Montebello cycle.	12	7
51	Sandstone, fine-grained, medium-gray; weathers to light olive gray; similar to unit 52, but with thinner beds, 2 to 8 in. thick.	8	
50	Sandstone, very fine grained, medium-dark-gray, very fossiliferous in lower 3 ft; bedding averages 1 to 2 in. in thickness; beds weather to fist-sized chunks.	12	6
49	Siltstone, medium-dark-gray; shaly partings.		4
48	Sandstone, fine-grained, medium-dark-gray, prominently jointed, laminated.	1	10
47	Sandstone, very fine to fine-grained, medium-dark-gray; bedding averages 1 to 3 in. in thickness; weathers to lumps.	2	5
46	Sandstone, very fine to fine-grained, medium-dark-gray; in one bed; jointing well developed.	1	8
45	Interbedded very fine grained sandstone and shaly-weathered siltstone, medium-dark-gray.	2	2
44	Sandstone, very fine grained, medium-dark-gray, laminated, jointed; lower part shaly.	1	2
43	Sandstone, very fine grained, dark-gray, very fossiliferous (*Mediospirifer*, *Tropidoleptus*).	1	2
42	Sandstone, fine- to medium-grained, medium-gray, well-laminated; conchoidal weathering on surface; 4-in.-thick local lens-shaped shaly band 2 ft from base.	7	10
41	Sandstone, very fine to fine-grained, medium-gray, finely laminated with muddy laminae; shaly partings.	1	5
40	Sandstone, fine-grained, medium-gray, laminated with muddy laminae; conchoidal weathering.	7	1
39	Sandstone, fine-grained, medium-gray, finely laminated with muddy laminae; shaly partings.	2	9
38	Sandstone, very fine grained, medium-gray, laminated with occasional muddy laminae; in one bed.		9
37	Sandstone, very fine grained, medium-dark-gray, laminated with shaly partings.		7
36	Sandstone, very fine to fine-grained, medium-gray, laminated, well-jointed.	2	11
35	Sandstone, fine-grained with muddy laminae, medium-gray, shaly partings.		9

Unit	Lithology	Thickness (feet)	Thickness (inches)
34	Sandstone, very fine to fine-grained, medium-gray.	1	3
33	Sandstone, fine-grained, very finely laminated; shaly partings.	2	1
32	Sandstone, very fine grained, medium-gray, well-laminated, jointed; conchoidal fracture.	35	4
31	Sandstone, very fine grained, medium-gray, with shale pebbles up to 3 in. long; fossiliferous. Unit cuts into top of Fisher Ridge Member in small scour.		4-8
	Fisher Ridge Member		
	(456 feet 10 inches (139 m) total thickness)		
30	Siltstone, medium-gray, sandy, shaly, finely laminated.	13	
29	Sandstone, very fine grained, medium-light-gray, laminated, well-jointed, tending to be shaly in upper 2 ft; conchoidal fracture.	16	3
28	Sandstone, very fine grained, medium-gray, finely interlaminated with muddy laminae, shaly; a few 1- to 3-in.-thick, light-weathering, very fine to fine-grained sandy layers in lower portion of unit. Two faults, having dips of 60°S, intersect this unit and thicken it by 2 ft. Upper 50 ft exposed in quarry no. 2; remainder is exposed on hill above quarry.	139	
27	Sandstone, very fine grained, and interbedded siltstone; medium-dark- to medium-gray, shaly, laminated.	29	7
26	Claystone, dark-gray, shaly; spheroidal weathering.	6	1
25	Claystone, dark-gray, shaly, and interbedded sandstone, very fine grained, medium-dark-gray, finely laminated.	3	3
24	Claystone, dark-gray, shaly; spheroidal weathering.	4	3
23	Sandstone, very fine to fine-grained, medium-gray, 50 percent interbedded with dark-gray shaly siltstone and dark-gray claystone.	16	1
22	Claystone to siltstone, dark-gray, with occasional lenses of medium-gray, very fine grained sandstone, finely laminated; shaly parting. No sandstone in lower half.	8	7
21	Sandstone, very fine grained, medium-gray, with some bands of finely laminated and crossbedded, light-gray sandstone, interbedded with dark- to medium-dark-gray siltstone; partially covered.	8	8
20	Siltstone, dark-gray, laminated with very fine grained sandstone laminae.		10
19	Sandstone, very fine to fine-grained, medium-gray, laminated, crossbedded, ferruginous.	1	1
18	Siltstone, medium-dark-gray, and interbedded sandstone, very fine to fine-grained, medium-dark- to dark-gray, finely laminated.	16	1
17	Claystone, dark-gray; shows slaty cleavage. Unit interrupted by a minor fault disrupting the lithology. Contains a lens of very fine grained sandstone from 4 to 12 in. thick and 3 ft in length, appearing to be a slump or flow roll.	2	
16	Sandstone, very fine grained, medium-dark-gray, laminated and interbedded with siltstone.	2	4
15	Claystone, medium-dark-gray, silty, shaly, laminated, interbedded with a few very fine grained, ferruginous sandstone beds; partially covered.	39	

Unit	Lithology	Thickness (feet)	Thickness (inches)
14	Claystone, moderate-brown to medium-dark-gray, silty; spheroidal weathering; weathers to pencil-shaped fragments.	8	9
13	Partially exposed silty claystone, moderate-brown, becoming less silty toward unit base; spheroidal weathering; weathers to pencil-shaped fragments.	83	
12	Claystone, medium-dark-gray, laminated, shaly.	10	
11	Interbedded and intermixed very fine grained, medium-gray sandstone and shaly siltstone. Unit is characterized by discontinuous layers and lenses of sandstone disrupted by slumping prior to lithification. Many of the sandstone layers are structureless internally but a few are crossbedded.	13	6
10	Sandstone, very fine grained, light-olive-gray, laminated and interbedded with siltstone, shaly, bedding-parallel.	2	6
9	Siltstone, dark-gray, shaly, with laminae increasing toward unit base; lenses of limestone, weathering dusky yellow, occur at 11 and 7 ft from unit top; limestone lenses gradually grade out into siltstone; laminae are continuous from siltstone into border of lenses; whole unit is covered with lichen growth and crust of mineralization.	33	
	Dalmatia Member		
	(70 feet 6 inches (21 m) exposed)		
8	Sandstone, very fine grained, medium-gray, calcareous, very hard; fractures across quartz grains.		7
7	Sandstone, very fine grained, calcareous, laminated, distinguished by shaly weathering.	2	
6	Sandstone, very fine grained, medium-gray, calcareous, very hard; fractures across quartz grains.	1	3
5	Sandstone, fine-grained, medium-gray, calcareous, laminated, sandy-weathering; lower few inches very limy and contain *Styliolina*.	2	4
	Along strike in quarry no. 3 units 5-8 are not calcareous and at the top grade up to very coarse grained sandstone with rare granules.		
4	Sandstone, fine-grained, medium-gray; contains a few siderite nodules.	2	
3	Sandstone, fine-grained, medium-gray; characterized by conchoidal weathering surfaces and total lack of visible layering; weathers light-olive-gray.	45	
2	Siltstone, shaly, dark-gray.		6
1	Sandstone, fine-grained, medium-gray, no layering. This unit is lowest observable rock at the south side of quarry no. 3.	16	

Mahantango Formation

Sherman Ridge Member	50′ 8″ (15 m) exposed
Montebello Member	378′10″ (117 m)
Fisher Ridge Member	456′10″ (139 m)
Dalmatia Member	70′ 8″ (21 m) exposed



FENCE DIAGRAM OF MIDDLE DEVONIAN STRATIGRAPHIC UNITS SUPERIMPOSED ON MAP OF THE MAHANTANGO FORMATION IN CENTRAL PENNSYLVANIA

BY

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1978